Chapter 6 - Appendix 1
Exploring data sets useful in assessing the effects of migratory flow conditions on the condition of chinook smolts transported from collector dams

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1.0 Introduction

With regard to transportation effects, it has been hypothesized that the survival of transported smolts may be sensitive to river discharge volumes experienced en route to the collector dam. Specifically, according to the hypothesis as flow levels decrease, fish condition degrades and transported smolts survive to adulthood at lower rates than would occur in higher flow years. To examine this hypothesis an assessment of fish condition upon arrival at a collector dam as related to prevailing flow volumes may be instructive. The species of interest in this analysis is chinook salmon, of which stream-type and ocean-type races are analyzed separately where data permits. I selected three dams that have been primary collection/transport sites over the years and have a reasonable time series of observations extending back to 1981; Lower Granite, Little Goose and McNary dams.

Lower Granite is the first collector dam smolts encounter on the Snake River. As such, observed smolt condition is not influenced by passage conditions associated with dam passage at other sites, but is influenced by migratory conditions prior to arriving at the dam and conditions within the bypass system at that site. In contrast, fish observed at LGO and many of those observed at MCN have encountered a number of dams en route to the collector dam. Thus, their condition reflects the collective migratory conditions experienced in reservoirs and those associated with cumulative dam passage. Since increasing flow volumes both increase reservoir water velocity and result in increased spillage when powerhouse capacity is exceeded, the collective migratory conditions should be beneficial and advantageous to the smolt population and may be reflected in the condition of smolts observed at these dams. It is possible that the conditions in the bypass at each collector dam may obfuscate effects associated specifically with conditions encountered during in river migration. Nevertheless, if in river conditions are a dominant factor dictating fish condition, there should be some evidence apparent in these data.

At collector dams, a sample of fish is examined daily to document fish condition. Descaling is one of the primary measures of fish condition that is regularly recorded. Additionally, biologists at the site estimate smolt mortality associated with collection and holding prior to loading on transport barges. Both descaling and smolt mortality observed at the facility have been reported annually in the Fish Transportation Oversight Team (FTOT) report series (1981-1992), and more recently as compiled in a separate but complementary report series by the USACE (data from 1993 report furnished by Dave Hurson, Walla Walla District USACE; more recent reports are not yet available). In those reports a descaled fish was defined as exhibiting scale loss within a number of predesignated areas. The number of descaled fish observed in the sample was then expressed as a percentage. During the years 1981-1995 Basham and Garrett (1996 draft) noted that descaling criteria changed. Thus they caution, "..descaling criteria will always have a level of subjectivity attached to the interpretation of a fish being descaled; however, the basic way that descaling rates were calculated followed along the same path." This suggests that across years the published descaling estimates are only useful as a general index of overall fish condition.

The mortality reported in the reports is the total number of dead smolts observed in the collection system, within the holding raceways (usually over a one to two-day period), and at the time of barge loading expressed as the percentage of the number of smolts estimated as collected at the dam. I used both the descaling and facility mortality indices as reported in those documents, as response variables in this analysis. Those data are tabulated in appendices 1-3 in this paper.

2.0 Lower Granite Dam

2.1 Inter-annual Changes in Descaling and Smolt Mortality

Using regression methods, we examined both inter- and intra-annual variability in the response variables, as related to prevailing river discharge levels in the Snake River. Given the working hypothesis, we expect that descaling and/or mortality observed at the facility should increase with decreasing flow. On an annual average basis, for the years 1981 through 1993, the percentage of the collected chinook classified as descaled ranged from 2.0 to 15.5 % (Appendix Table 1), and mortality observed at the fish collection and holding facility ranged from 0.3 to 1.2 %. These estimates are based on observations that include both stream-type and ocean-type chinook combined. Two flow indices (mean flow during May and June separately)were used to examine for flow-related correlations with the response variables. Additionally, mean water temperature in May offered another index of river condition that could influence fish condition observed at Lower Granite Dam.

2.1.1 Descaling:

Using data from 1981-1993, we examined bivariate regressions and observed no significant correlation between the annual descaling index for chinook salmon at Lower Granite Dam and either mean flow for May or June, or mean water temperature during the month of May. The r-squared values were small ranging from 0.01 to 0.09 for linear models. Logarithmic, exponential and reciprocal models did not appreciably change the r-squared values. There is no evidence that flow conditions influenced the frequency of descaled fish observed at the dam.

The proportion of the chinook population classified as descaled in 1981 and 1982 was extremely high in comparison to all other years, at 15.5 and 8.8 %, respectively. The FTOT reports for those years indicated that debris loads at the dam and within the fish facility were very high, and accounted for the high frequency of descaling.

2.1.2 Facility Mortality:

Similar results were apparent in bivariate regression models using annual indices of chinook smolt mortality observed at the collection facility as the response variable and the same water condition indices as predictor variables. No significant correlations were observed; with r-squared values ranging from 0.02 to 0.13 for linear models, and no substantive improvement for logarithmic, exponential and reciprocal models. As a related point of interest, smolt mortality was not correlated with the frequency of descaling observed at the dam; r-squared = 0.05.

2.2 Intra-annual Changes in Descaling

In the FTOT reports, descaling estimates are also tabulated on a weekly basis (Appendix Table 2). We examined in-season changes in the proportion of the chinook smolt population classified as descaled for the years 1991-1993 (the most recent years as yet published). Weekly indices of smolt mortality were not reported. We focused on the spring migration period through 1 July, when stream-type chinook are the dominant chinook race. We did not consider later dates because after June weekly samples typically drop below 100 fish, and are dominated by small numbers of ocean-type chinook.

Snake River discharge spanned a broad range of conditions over these years. 1992 was one of the lowest runoff years observed in several decades, whereas runoff conditions in 1993 were moderate to high during May. The weekly descaling indices reported by FTOT and the Snake River discharge volume on the last day of each week is reported in Appendix Table 1. We observed no significant correlations between weekly descaling indices and associated flow indices for any of the three years examined. In 1991, descaling rates ranged from 0.3 to 5.9 %: no correlation with the weekly flow index was observed (Appendix Table 1). In 1992, river discharge was consistently low, with flow indices ranging from 20 to 67 kcfs. In that year, descaling percentages ranged from 3 to 7.4 %, with no correlation with flow volume apparent (Appendix Table 1). The broadest range in river discharge occurred during 1993, when the flow index ranged from 49 to 177 kcfs. That year the descaling index ranged from 0 to 5.6 % for wild fish and 3 to 6.4 % for hatchery fish with no correlation with flow volume indicated (Appendix Table 1).

Table C6 A1-1: Correlation between weekly descaling indices for chinook salmon smolts and daily average flow on the last day of each week, for the period extending from the start of the spring migration through about 1 July each year. 1993 was the first year that separate measurements for wild and hatchery chinook were reported.

	1991	1992	1993 Hatchery	1993 Wild
R-squared	0.40	0.14	0.04	0.01
P	0.19	0.24	0.57	0.83

These data and analyses do not support the working hypothesis, i.e., the condition of smolts loaded into barges degrades under low flow conditions encountered during migration to Lower Granite Dam. Neither the level of descaling observed at the dam, nor smolt mortality observed in the holding facilities were correlated with the river discharge volumes encountered during migration to the dam. Comparisons across years and within recent years yield similar results.

3.0 Little Goose Dam

We examined data at Little Goose Dam to see if it comports with results from Lower Granite Dam. Data from both sites yielded the same results. Flow indices did not explain the observed variability in either mortality or descaling observed at LGO.

3.1 Inter-annual Changes in Descaling and Smolt Mortality

Using regression methods, we examined inter-annual variability in the response variables, as related to prevailing river discharge levels in the Snake River. Given the working hypothesis, we expect that descaling and/or mortality observed at the facility should increase with decreasing flow. These estimates are based on observations that include only stream-type chinook.

3.1.1 Descaling:

On an annual average basis, for the years 1981 through 1993, the percentage of yearling chinook classified as descaled ranged from 3.7 to 26.0 % (Appendix Table 2). No significant correlation between the annual descaling index for chinook salmon and mean flow for May was evident (r-squared = 0.13). Logarithmic, exponential and reciprocal models did not appreciably change the r-squared values. This is consistent with findings at Lower Granite Dam.

3.1.2 Facility Mortality:

Mortality observed at the fish collection and holding facility ranged from 0.1 to 8.4 %. There was no obvious relationship between smolt mortality and flow indices. No significant correlation was observed (r-squared = 0.169).

The absence of any relationship between the response variables and Snake River discharge is consistent with the results obtained at Lower Granite Dam immediately upstream. These data and analyses do not support the working hypothesis that the condition of smolts loaded into barges degrades with their exposure to decreasing flows encountered during migration to Little Goose Dam.

4.0 Mcnary Dam

The composition of the chinook salmon population arriving at McNary Dam is heavily skewed toward Mid-Columbia stocks, since during the years used in these analyses, the Snake River transportation program removed the majority of Snake River smolts.

4.1 Stream-type yearling chinook

Most of these fish emanate from tributaries upstream from Rock Island Dam and have encountered several hydroelectric projects en route to MCN. The majority of the yearling chinook population passes MCN during the month of May. I used the mean flow for that month as the index for river discharge conditions.

There was no correlation between the variation in smolt mortality observed at the fish facility and prevailing river discharge volumes as indexed at McNary Dam (r-squared = 0.062). However, descaling incidence was positively and significantly correlated with flow volumes (r-squared = 0.559, p= 0.005) (Figure 1). According to the working hypothesis one would expect a negative, rather than positive correlation between descaling and flow.

4.2 Ocean-type subyearling chinook

Most ocean-type subyearling chinook arriving at McNary Dam are produced from a wild stock in the Hanford Reach and from Priest Rapids Hatchery. McNary is the first dam these stocks encounter. Subyearling chinook pass McNary Dam during June and continuing through July. In these analyses, both flow and water temperature indices (means for June) were used as predictor variables. Using stepwise multiple regression we found that using smolt mortality as the response variable the only predictor variable to enter the model was flow ($r = 0.628$, $p = 0.029$), with mortality decreasing with increasing flows (Figure 2):

- % Mortality = 4.596 - 0.0104 (June Flow)

However, descaling was positively correlated with flow (Figure 3), as was apparent for yearling chinook at McNary Dam. Using stepwise multiple regression only flow entered the model ($r = 0.701$, $p = 0.011$):
% Descaled = -1.345 + 0.0169 (June Flow)

The two performance measures present conflicting story lines with respect to the working hypothesis. Based on mortality observed at the dam, only subyearling chinook exhibited a significant relationship, where facility mortality decreased with increasing river discharge. If this is an instructive performance measure with respect to flow effects on fish condition and subsequent long-term survival, then there is evidence to support the working hypothesis for this race of chinook transported from this dam. However, there is no such indication for yearling chinook salmon.

In contrast, both races of chinook displayed a significant positive relationship between the frequency of descaling observed at MCN and river discharge. If descaling is a useful indicator of fish condition, then high flows may compromise long-term performance of the population; a situation which contradicts the working hypothesis.

5.0 Discussion

According to the working hypothesis fish condition is lower in years of low runoff when river discharge is low, and thus transported smolts could incur higher mortality in years of low runoff. For yearling chinook salmon, during the years 1981-1993, there is no indication that the condition of fish loaded into transport vessels varied with river discharge volumes prevailing during the migratory period. Neither fish mortality observed at the dam nor the incidence of descaling increased as discharge decreased. This holds for all three dams. Unexpectedly, at McNary Dam a significant positive relationship was evident, with descaling increasing as flows increased. Based on that performance measure at that site the condition of stream-type chinook transported from MCN may have been compromised at increasing flows.

Recall that at LGR the data are not reported separately for yearling and subyearling chinook. However, the ocean-type subyearling fall chinook population is only a small fraction of the total chinook smolt population passing LGR. For example in 1993 the passage indices for yearling and subyearling chinook at LGR were 1,918,200 and 16,500 smolts, respectively. Thus LGR results pertain primarily to yearling chinook.

An issue worth discussing is how useful the descaling index is for predicting the long-term survival of salmon. There was no correlation between descaling and acute short-term smolt mortality observed at the holding facilities, suggesting there may be little connection. However, Bouck and Smith (1979) experimentally tested the effects of descaling on coho smolts. They scraped 25% of the scales in an experimental lot and found that none died when subsequently held in freshwater, but 75% died during that same period when directly liberated into seawater. They also reported that tolerance to seawater was soon restored if fish were allowed to remain in fresh water for a few days following scale removal. With two days in fresh water, 95% of the descaled smolts survived seawater entry. Presuming these results also generally apply to chinook salmon, it suggests that smolts descaled at dams or during transport should fare well if they reside in fresh water for two or more days prior to seawater entry.

Ocean-type subyearling chinook arriving at McNary Dam present conflicting story lines with respect to the working hypothesis. Based on mortality observed at the dam, smolts exhibited a significant relationship consistent with the working hypothesis; mortality decreased with increasing river discharge. However, descaling for subyearling chinook increased with increasing flow, a condition inconsistent with the working hypothesis. The question remains as to whether either of these performance measures are indicators of long-term survival, because they portend different consequences.

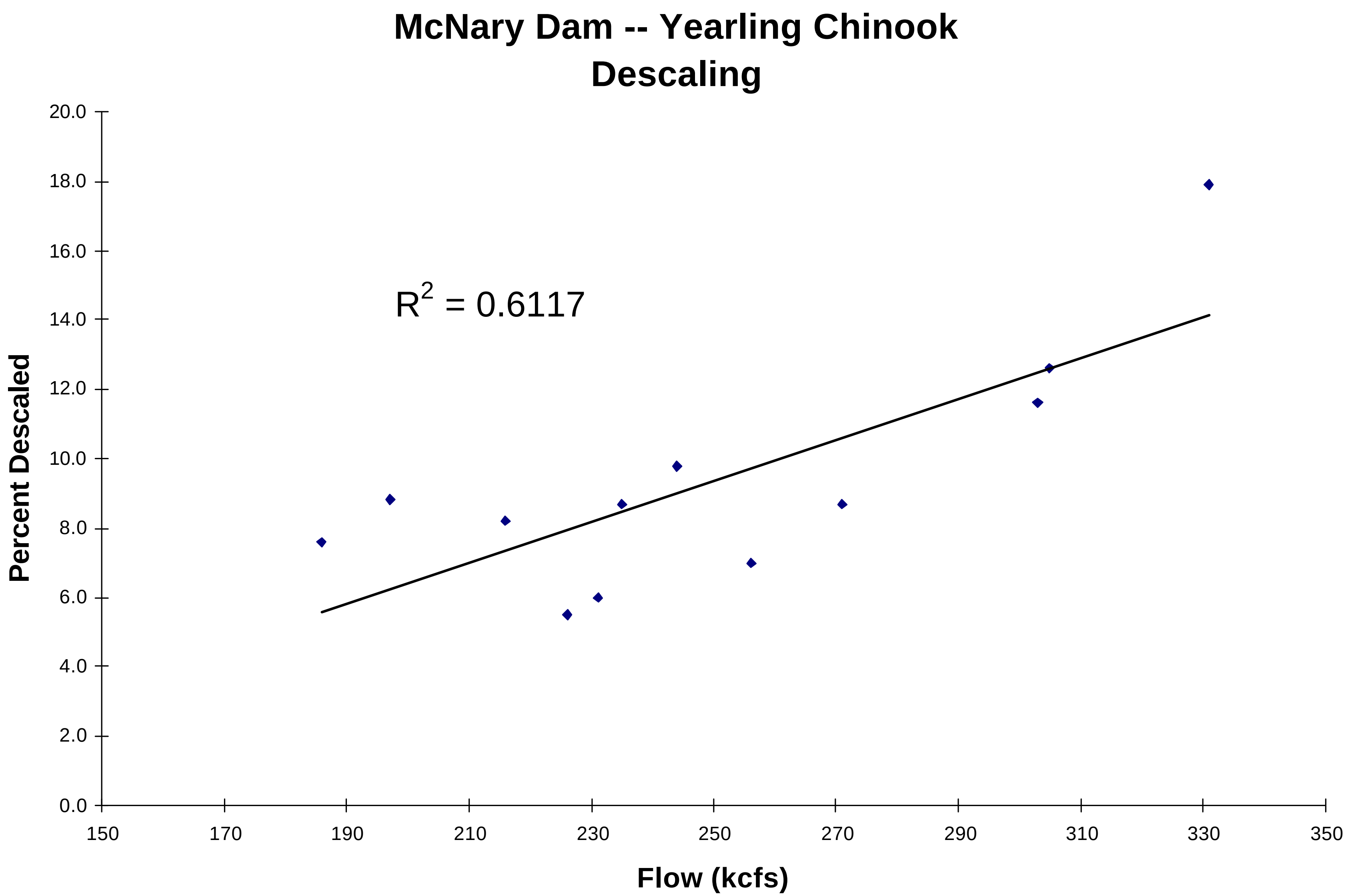
Since fish condition as observed at the collector dams reflects both effects associated with river migration as well as conditions encountered while passing through the collection system, it is possible flow effects could be masked. For example, as noted previously, in 1981 and 1982 very high descaling was observed at LGR and attributed to high debris loads at the dam and within the fish facility. Subsequent to that, debris removal efforts have been intensified, and systematic removal is a standard practice. Furthermore, as noted previously, descaling criteria have changed during the transportation era, and another element of uncertainty as to the comparability of indices across years. Nevertheless, if flow effects are an important factor affecting the condition of yearling chinook, some indication was expected in the available data, especially since three different sites across several years, and within season variability at LGR in three recent years were inspected. Ideally, to separate facility effects from flow-related effects, it is preferable to sample smolts before they encounter the collection system at any dam. This would require a sampling effort staged in the forebay.

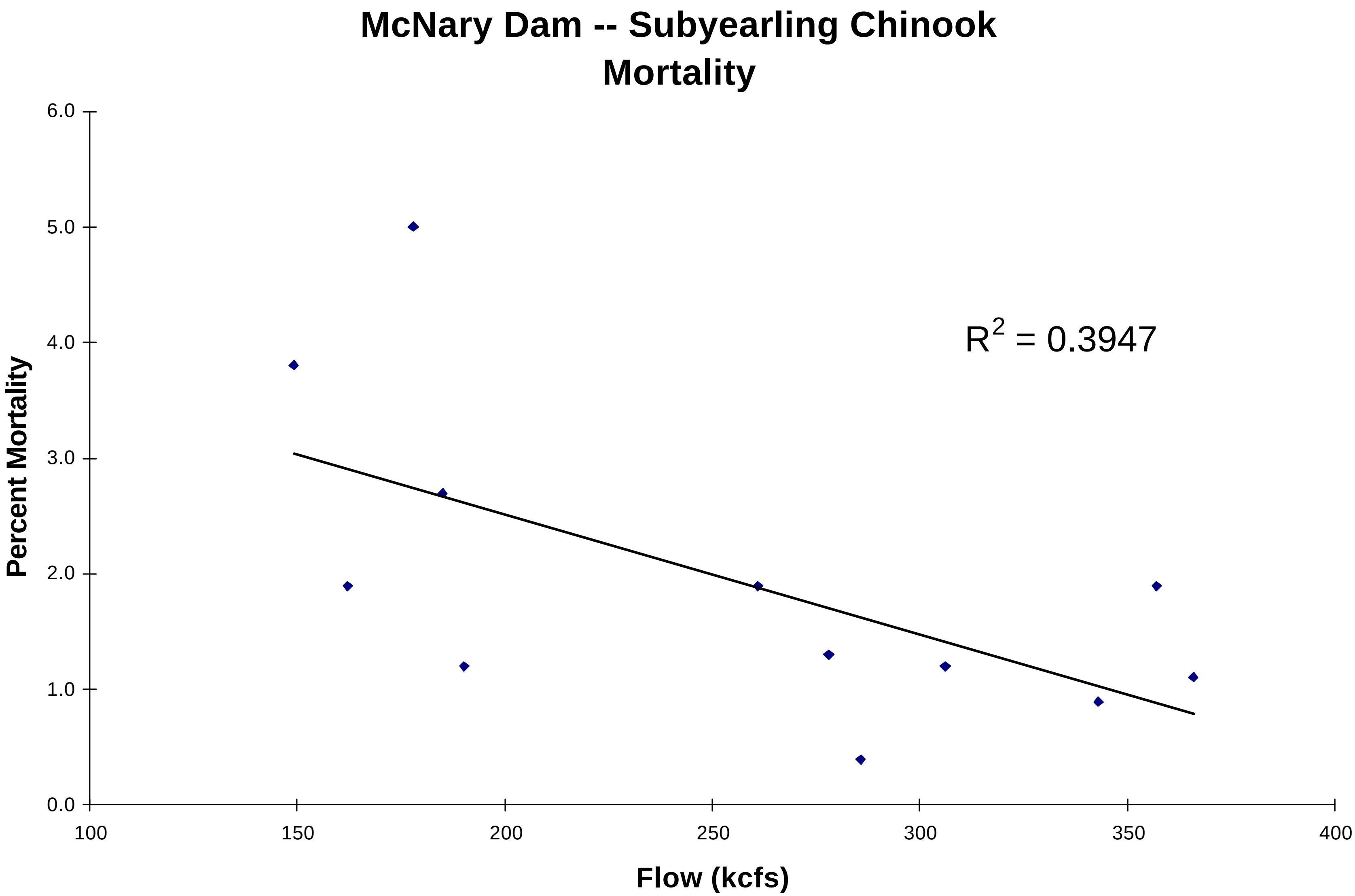
In summary, with the exception of subyearling chinook salmon collected at MCN, there was no positive relationship between fish condition and prevailing river discharge as indexed during the migratory period. At McNary Dam subyearling chinook exhibited a significant negative relationship between mortality and flow, but a positive correlation with descaling and flow.

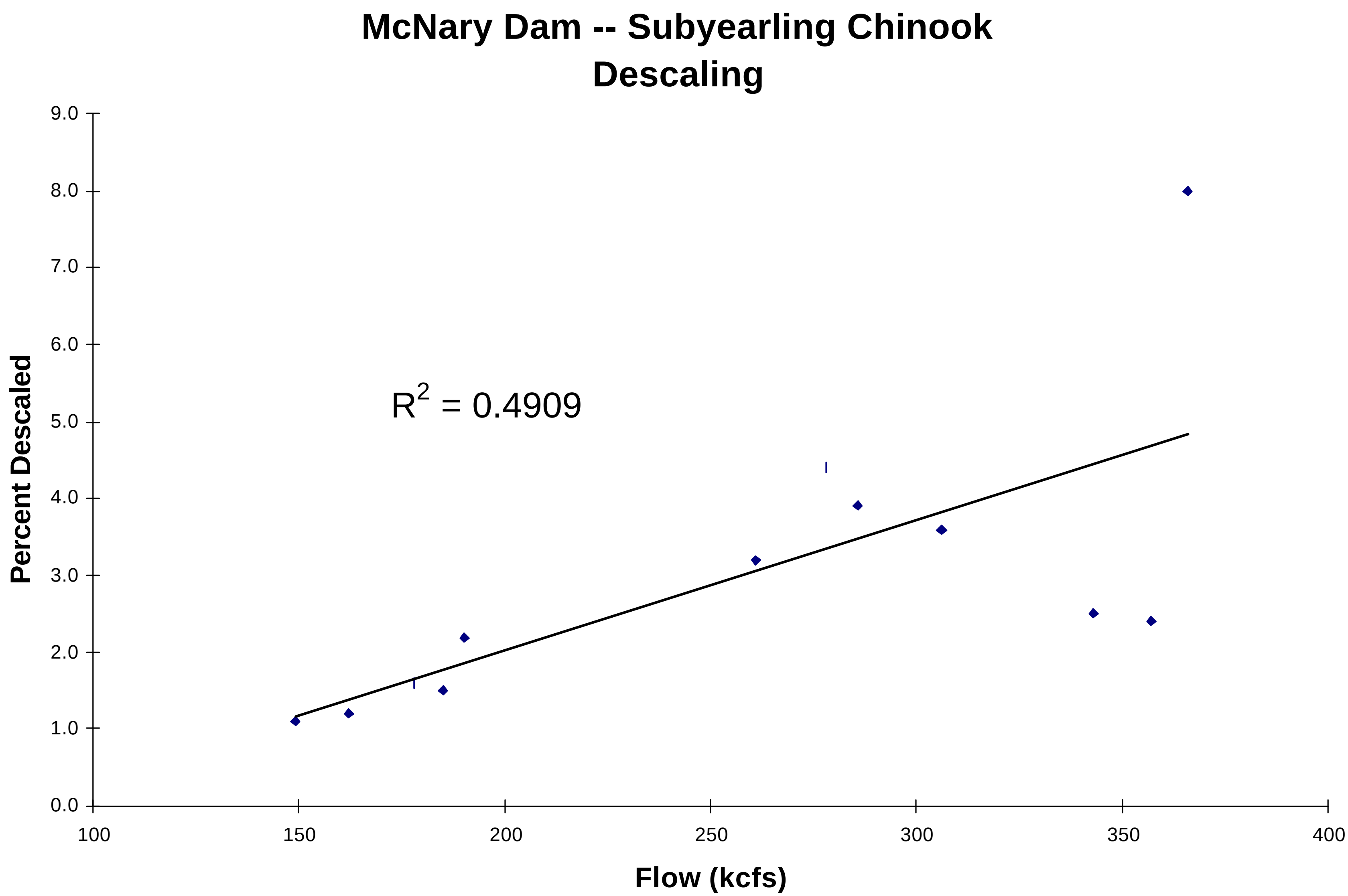
6.0 Literature Cited

Bouck, G., and S. Smith. 1979. Mortality of experimentally descaled smolts of coho salmon (Oncorhynchus kisutch) in fresh and salt water. Trans. Amer. Fish. Soc. 108:67-69.

Basham, L., and L. Garrett. 1996 draft. Historical review of juvenile fish descaling information collected at the Columbia and Snake River transportation projects. Draft report submitted to PATH, In Preliminary Report on Retrospective Analyses.


McNary Dam -- Yearling Chinook
Descaling
$R^2 = 0.6117$
Percent Descaled
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
150
170
190
210
230
250
270
290
310
330
350
Flow (kcfs)


McNary Dam -- Subyearling Chinook Mortality
Percent Mortality
Flow (kcfs)
$R^2 = 0.3947$
6.0
5.0
4.0
3.0
2.0
1.0
0.0
100
150
200
250
300
350
400


McNary Dam -- Subyearling Chinook
Descaling
Percent Descaled
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
R2 = 0.4909
100
150
200
250
300
350
400
Flow (kcfs)

Appendix Table 1. Lower Granite Dam Annual Average Descaling and Mortality.
Data from FTOT and COE Fish Passage Reports

	Chinook		Mean Flow (kcfs)		Mean Temp.
Year	Descaling	Mortality	May	June	May
1981	15.5	0.7	91.5	119.3	53.9
1982	8.8	0.8	137.1	156.8	51.9
1983	3.0	0.7	122.2	131.4	54.7
1984	3.0	0.5	155.2	184.9	51.0
1985	2.0	0.3	91.2	74.7	53.0
1986	3.7	0.3	112.0	115.5	52.6
1987	3.3	1.2	63.9	29.3	55.0
1988	2.4	0.5	68.6	48.2	54.3
1989	2.3	0.9	82.5	73.1	52.4
1990	3.6	0.3	68.2	77.5	53.7
1991	2.4	0.3	80.4	76.6	49.7
1992	4.9	0.6	60.0	29.8	55.5
1993	3.9	0.4	131.4	98.8	53.4

Weekly Mean Descale Values for Yearling Chinook

	1991		1992		1993		
Week Ending	% Descaled	Flow (kcfs)	% Descaled	Flow (kcfs)	% Descaled (H)	% Descaled (W)	Flow (kcfs)
15-Apr	1.4	24.0	3.3	42.0			
22-Apr	1.4	30.0	6.6	45.0	3.2	0.0	65.0
29-Apr	2.0	59.0	6.9	49.0	3.0	1.0	66.0
6-May	3.4	44.0	7.4	75.0	5.4	1.9	101.0
13-May	5.9	81.0	4.4	51.0	3.8	4.0	112.0
20-May	3.3	97.0	3.9	47.0	5.0	1.8	177.0
27-May	3.3	95.0	4.7	67.0	6.4	1.5	131.0
3-Jun	2.6	85.0	5.0	58.0	2.6	0.8	120.0
10-Jun	1.0	78.0	3.0	38.0	4.2	2.7	111.0
17-Jun	2.3	66.0	3.9	23.0	6.4	3.9	106.0
24-Jun	0.4	60.0	4.9	20.0	3.8	5.6	86.0
1-Jul	0.3	65.0	5.5	20.0	5.9	3.5	49.0

This table excludes information beyond 1 July because weekly samples were small (< 100), and subyearling chinook dominated the catch during July.

Flow index = discharge on last day of the week indicated.

Appendix Table 2. Little Goose Dam; yearling chinook mortality (%) and descaled fish (%) observed at dam, 1981 - 1993. Data from FTOT reports and USACE Fish Passage Reports.

Year	% Mortality	% Descaled	May Flow mean kcfs
1981	1.3	15.4	91.5
1982	6.2	26.0	137.1
1983	2.7	18.4	122.2
1984	1.5	7.1	155.2
1985	1.0	7.9	91.2
1986	0.9	8.8	112.0
1987	1.8	8.6	63.9
1988	1.2	12.7	68.6
1989	1.5	9.9	82.5
1990	1.1	6.5	68.2
1991	0.9	3.7	80.4
1992	0.4	4.2	60.0
1993	0.3	5.0	131.4

Appendix Table 3. McNary Dam descaling and mortality data, 1981-1992. Data taken from annual FTOT and COE Fish Passage Reports.

Subyearling Chinook

			June	
Year	% Mortality	% Descaled	Flow (kcfs)	Temperature
1981	1.9	2.4	357.0	57.4
1982	1.1	8.0	366.0	57.4
1983	0.4	3.9	286.0	60.6
1984	0.9	2.5	343.0	56.9
1985	2.7	1.5	185.0	61.1
1986	1.9	3.2	261.0	62.0
1987	3.8	1.1	149.0	61.2
1988	1.9	1.2	162.0	61.2
1989	1.2	2.2	190.0	61.4
1990	1.2	3.6	306.0	58.7
1991	1.3	4.4	278.0	57.3
1992	5.0	1.6	178.0	63.1

Yearling Chinook

Year	% Mortality	% Descaled	May Flow (kcfs)
1981	0.9	8.7	235.0
1982	1.8	17.9	331.0
1983	0.5	11.6	303.0
1984	0.3	12.6	305.0
1985	0.4	6.0	231.0
1986	0.5	7.0	256.0
1987	0.8	5.5	226.0
1988	1.4	7.6	186.0
1989	0.4	9.8	244.0
1990	1.2	8.2	216.0
1991	0.7	8.7	271.0
1992	1.9	8.8	197.0

Flow index = mean flow (kcfs) during May as measured at McNary Dam.